Microturbine and Industrial Gas Turbine

Peer Review Meeting

Microturbine Market Review

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ENERGY NEXUS GROUP

Presentation Topics

- Microturbine Attributes
- Market Applications and Technical Potential
- Economic Market Potential (AMTS)
- Market Issues

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Microturbine Attributes

- Simple, compact, few moving parts – potential for low cost in adequate volumes
- Potential for low maintenance costs
- Low emissions – easier to site, important societal benefits
- Fuel flexibility – natural gas, liquid fuels, waste fuels, variable quality
- Operational flexibility – turndown ratio, start time, daily cycling or load following, black start, independent or parallel
- Power electronics - power quality, integration with UPS, synergies with other DER technologies
- Useable thermal energy -- direct use of exhaust, hot water or low pressure steam

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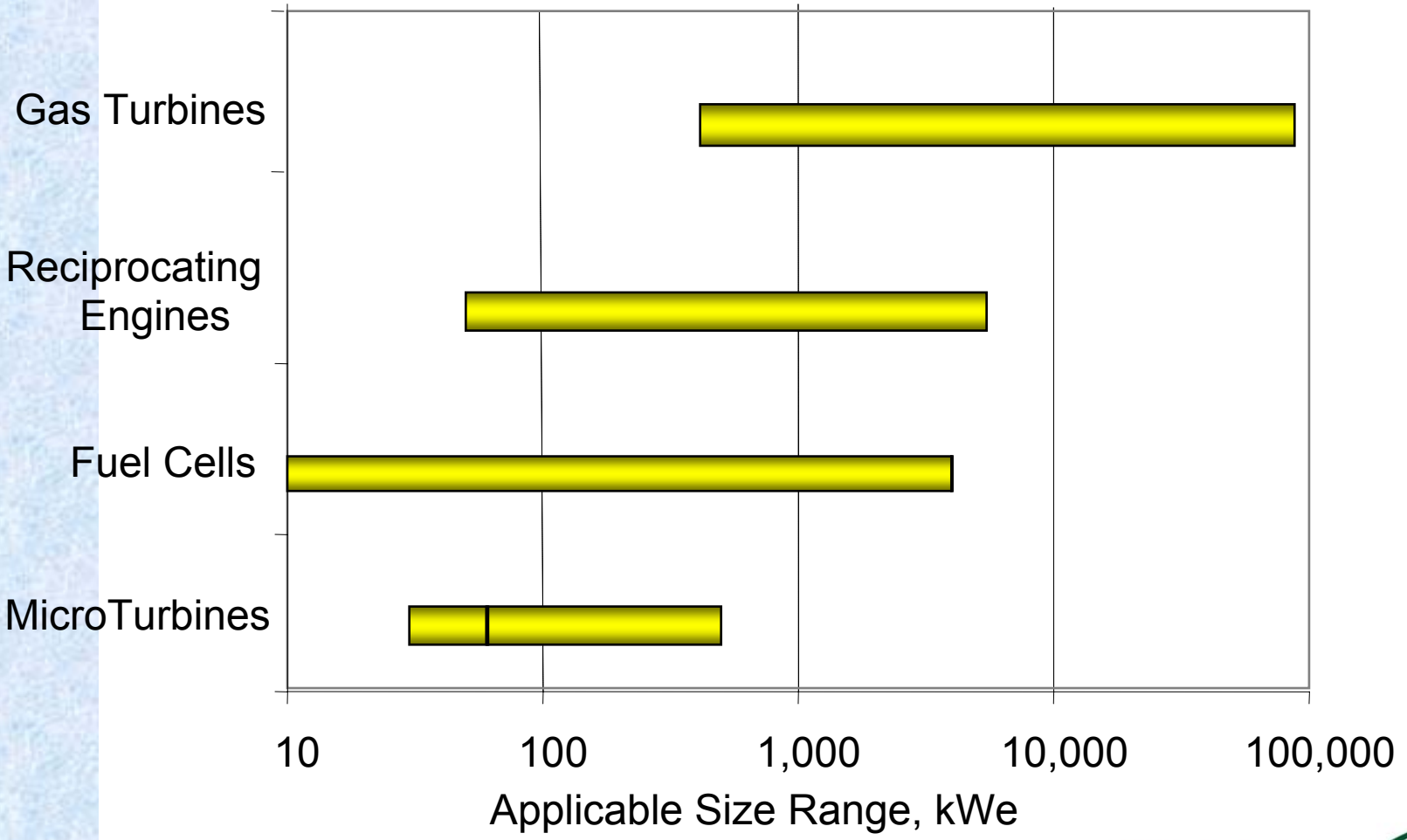
Technology Coverage



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Potential Applications

- ***Combined Heat and Power*** - common practice by large industrials; large untapped potential in small industrial and commercial
- ***Power-Only*** - baseload power in high electric price areas; emerging market to provide quality power to sensitive customers
- ***Peaking*** - potential growth market for customer peak shaving (500 to 2000 hours/year) by light industrial and commercial
- ***Niche Applications*** - providing power in remote or isolated applications, shut in gas wells, and other niche markets such as landfill and municipal waste

Combined Heat and Power

- Traditionally the most effective DG option
- CHP is attractive from an energy policy perspective
- Requires steady on-site thermal loads
- *High operating hours needed to cover high capital costs*
- *Total system efficiency is key to economics*
- *O&M costs are critical*
- *Emissions*

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CHP-Hot Water

- Traditional CHP applications in commercial and small industrial
- Requires steady on-site thermal load
- Large potential but limited existing market penetration in < 1 MW applications
- *Technical Potential*

  30 to 50,000 MW

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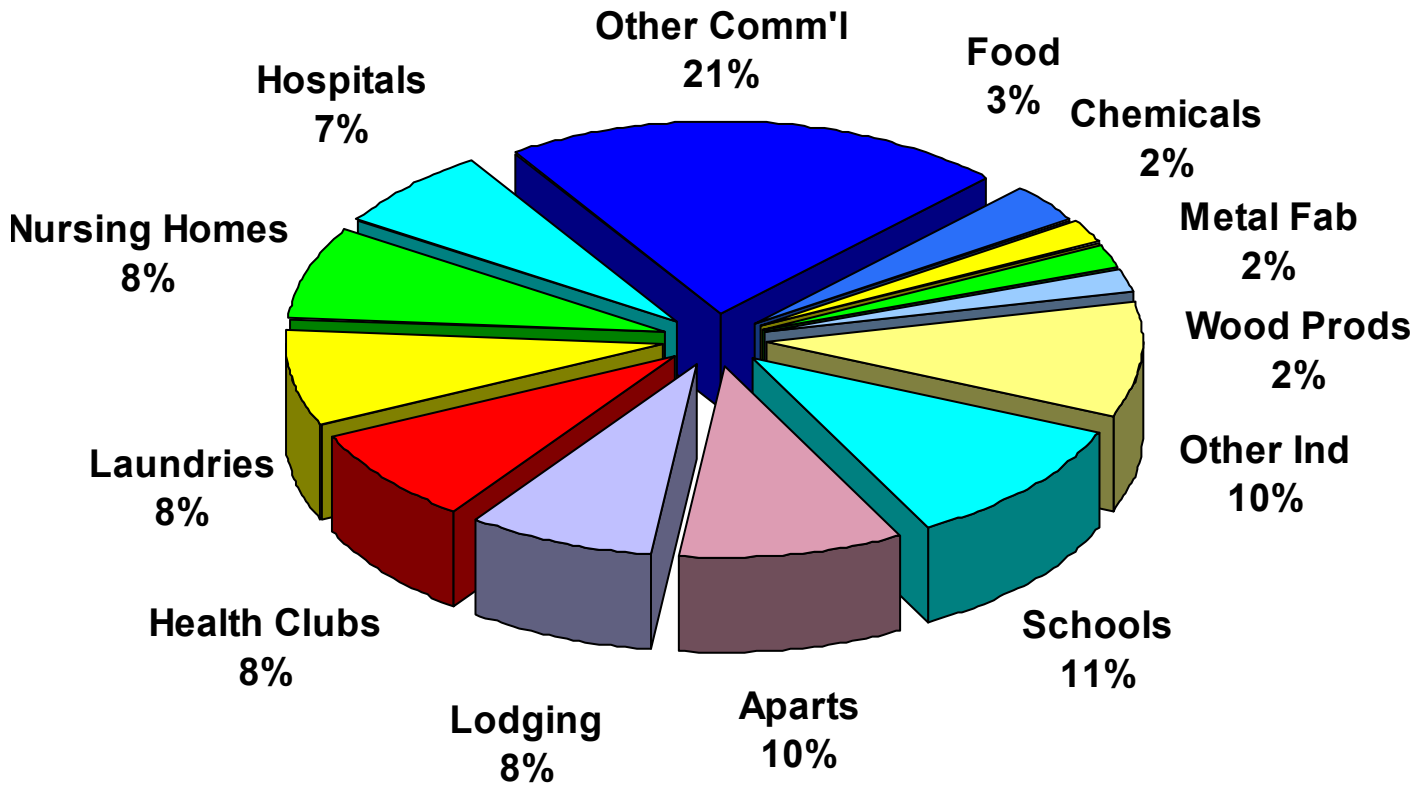
Existing CHP < 1 MW

- *190 MW, 970 sites*



Source: Hagler Bailly, Nexus

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Cooling, Heating and Power

- Converts building electric load for cooling to thermal, improving load factor, increasing economic sizing, and enhancing thermal utilization
- Requires heat recovery boiler, absorption chiller, cooling tower -- high capital cost system
- Increases penetration of the office, food service and certain retail sectors
- *Technical potential: 40 to 60,000 MW*

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CHP-Direct Heat

- Direct use of MT exhaust for process heat or preheat -- low emissions, no lube oil, high oxygen content
- Eliminates the heat recovery boiler
- Lower cost than traditional CHP so economic fit is broader geographically
- Limited number of low temperature industrial applications – plastics, wood products, textiles, specialty chemicals
- *Technical Potential: 5 to 10,000 MW*

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Power Only - Baseload

- Simple system, no heat recovery, simplified design and installation
- Widespread applicability -- customers with year round power use in industrial and commercial applications in the target size range
- With no thermal credit, power costs are higher
- Grid connected systems can be sized to run continuously, remote power systems must meet the total needs of the site.
- *Electrical efficiency, O&M costs, reliability are key; power quality key for certain customers*
- *Emissions in certain areas*
- *Technical Potential: 40 to 60,000 MW*

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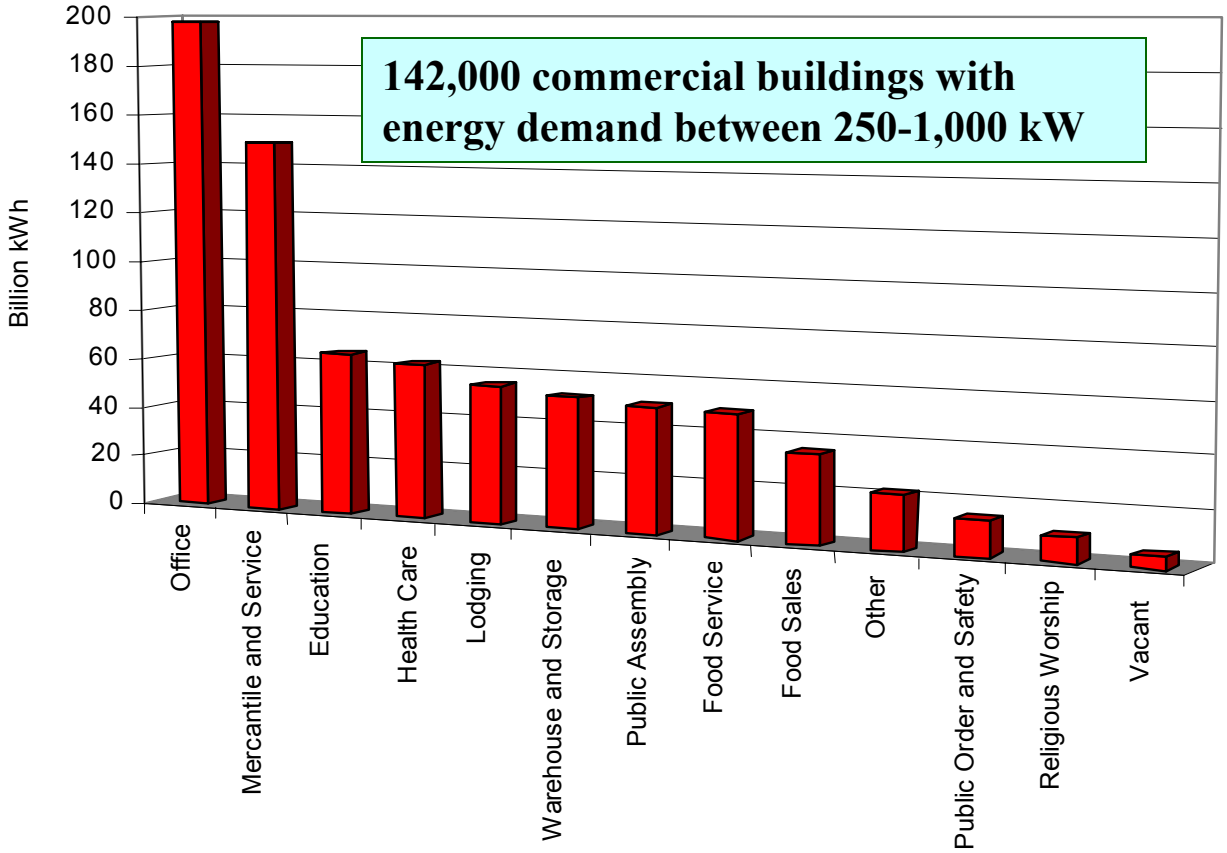
Commercial Power Market



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Peak Shaving

- Simplified design and installation
- 50 to 3000+ hours per year
- *Efficiency not critical*
- *Low capital cost and low fixed O&M costs are important*
- *Availability / reliability are key*
- *Emissions if hours are high*

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Peak Shaving Strategies

Type	Description	Annual Hours of Operation
Independent	Operate during peak or high cost periods on published rates	900-3,500
Coordinated	Operate on utility coordinated program or interruptible rate	50-400
Competitive	Operate according to hourly power costs either independently or on an aggregation contract	50-??

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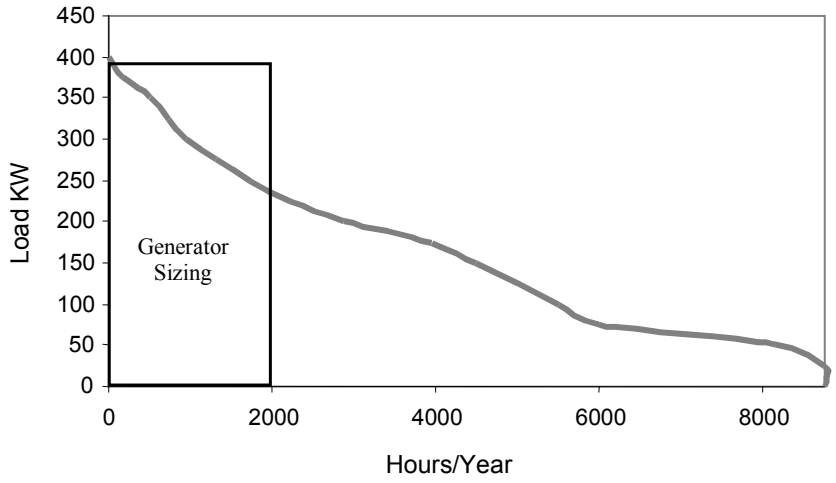
Peak Shaving



- Widespread technical market applicability
- Economics depend on rates
- Peak shaving modes
  - ✓ Peak shaving against published rates
  - ✓ Interactive utility programs
- *Technical Potential:*

  80,000 MW

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Peak Shaving with Reliability

- System provides both economic peak shaving and emergency back-up capability
- Markets limited to those customers who want or need a back-up power source
- Added value equal to the cost of an avoided diesel generator
- Applications include hospitals, communications, financial, certain industrial applications
- *Technical potential: 15 to 20,000 MW*

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Resource Recovery

- Oil and gas wells, land fills
- Compete against tariff electric and new lines
- *Efficiency not critical, fuel is "free"*
- *Fuel flexibility is important*
- *Availability / reliability are key*
- *Unattended operation and predictable maintenance*

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Waste Fuel Systems

- Characterized by variable and often poor quality fuels
- Largest potential in recovery of methane from landfills and in the use of digester gas in sewage treatment
- Other potential markets -- feedlots and coalbed methane
- *Technical Potential:*

  <1000 MW

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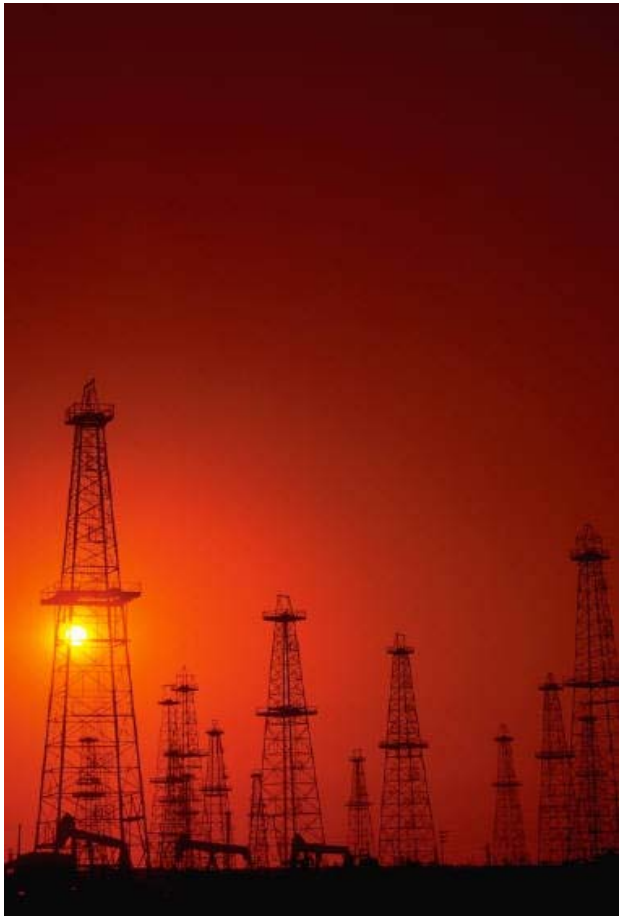
Oil and Gas Industry



- Fuel flexibility and use of fuels that would otherwise be wasted: flare gas, casing head gas, sour gas
- Converting remote gas to power
- *Technical Potential:*

  2,000 to 5,000 MW

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Economic Competitiveness

- We compared the cost of power from the AMTS with the range of commercial power prices paid in the U.S.
- This comparison shows the competitiveness of the AMTS in a variety of applications previously described
- In addition, qualitative comments on the positioning of the AMTS in the future DG market are provided

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Electric Power Prices

- The power prices paid by commercial customers are representative of the markets that will be addressed by the AMTS
- EIA data show that these prices range (state-by-state) from over 15 cents/kWh to about 4 cents/kWh
- Comparing these average electric prices to average consumption by state and then ordering from highest price to lowest provides a measure of the quantitative distribution of prices in the U.S.

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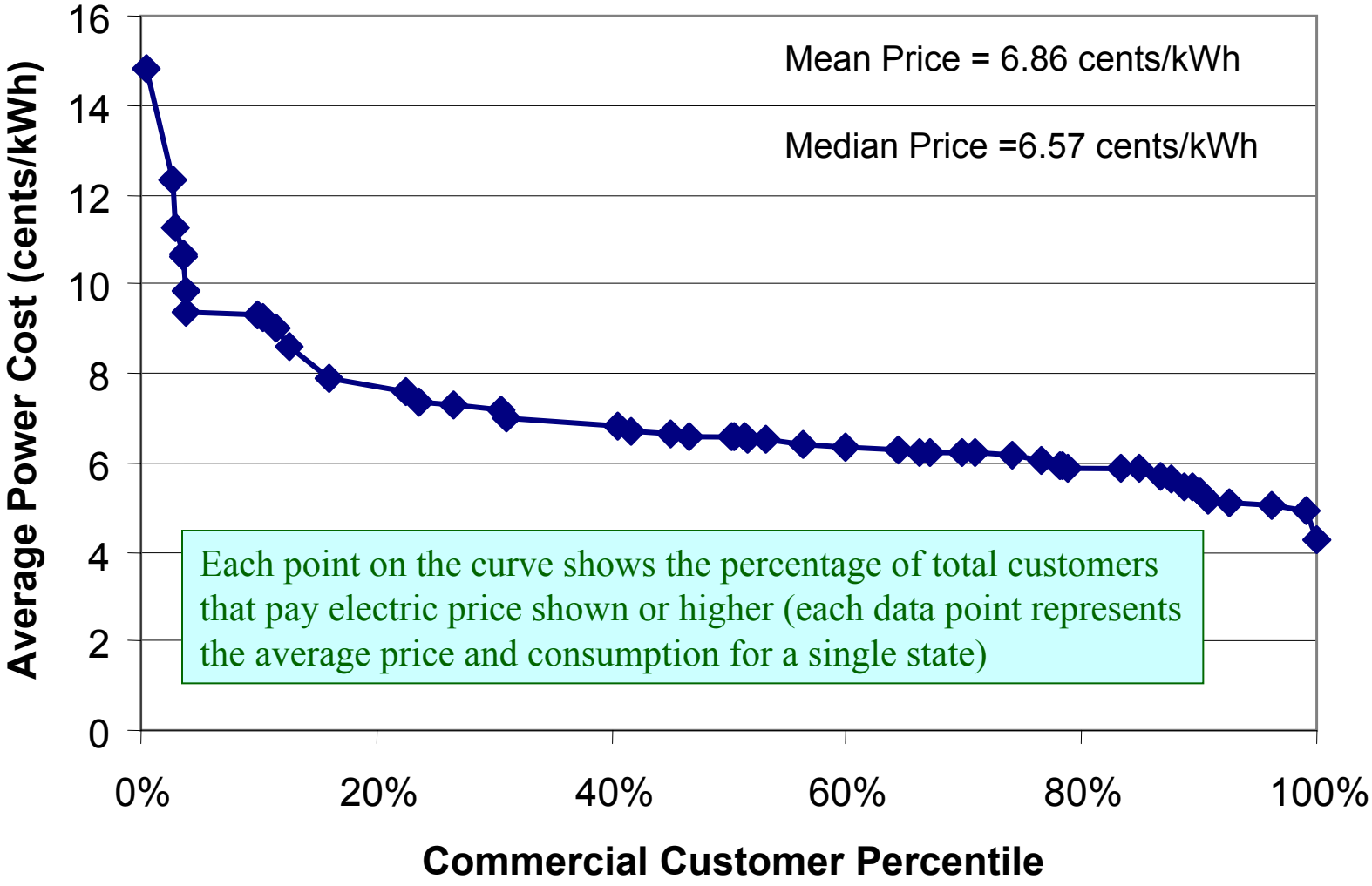
Distribution of Commercial Power Prices

2000



Comparison of AMTS to Commercial Power Prices

- For this comparison, the average net power costs for AMTS have been calculated for a variety of continuous applications (intermittent power applications are also competitive for the AMTS but not analyzed here)
  - ✓ Baseload Power Only
  - ✓ Direct CHP (using the clean exhaust directly)
  - ✓ Hot Water CHP
  - ✓ Cooling, Heating and Power for Building s
  - ✓ Waste fuel applications such as digester gas or landfill gas
- These calculations can then be compared with the range of power prices in the U.S. that were shown on the previous slide

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AMTS Power Costs

Continuous AMTS Application	Installed Cost $/kW	Overall Efficiency	Net Power Cost cents/kWh
Baseload Power Only	$900	36.0%	$0.083
CHP-Hot Water	$1,050	75.0%	$0.066
Direct CHP	$950	85.0%	$0.059
BCHP (current absorber technology)	$1,300	69.0%	$0.075
Waste Fuel: Digester or Landfill Gas	$1,000	36.0%	$0.028

Assumptions:

Package Cost = $500 to 600/kW

O&M Cost = 1.2 cents/kWh

Gas Cost = $5.50/MMBtu (except waste fuels are free)

Meets overhaul and economic life targets of the AMTS program

Capital recovery factor = 16.3% per year, 10 year life, 10% return

All systems include interconnect costs for parallel operation with utility.

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AMTS versus Purchased Power

- The competitive share of the market ranges from 20% to 80% of the total market depending on the application -- not counting waste applications which should have universal competitiveness

- The following chart overlays the range of AMTS power costs onto the U.S. power cost curve showing the range of competition -- 20-80% of the relevant customer base for each application

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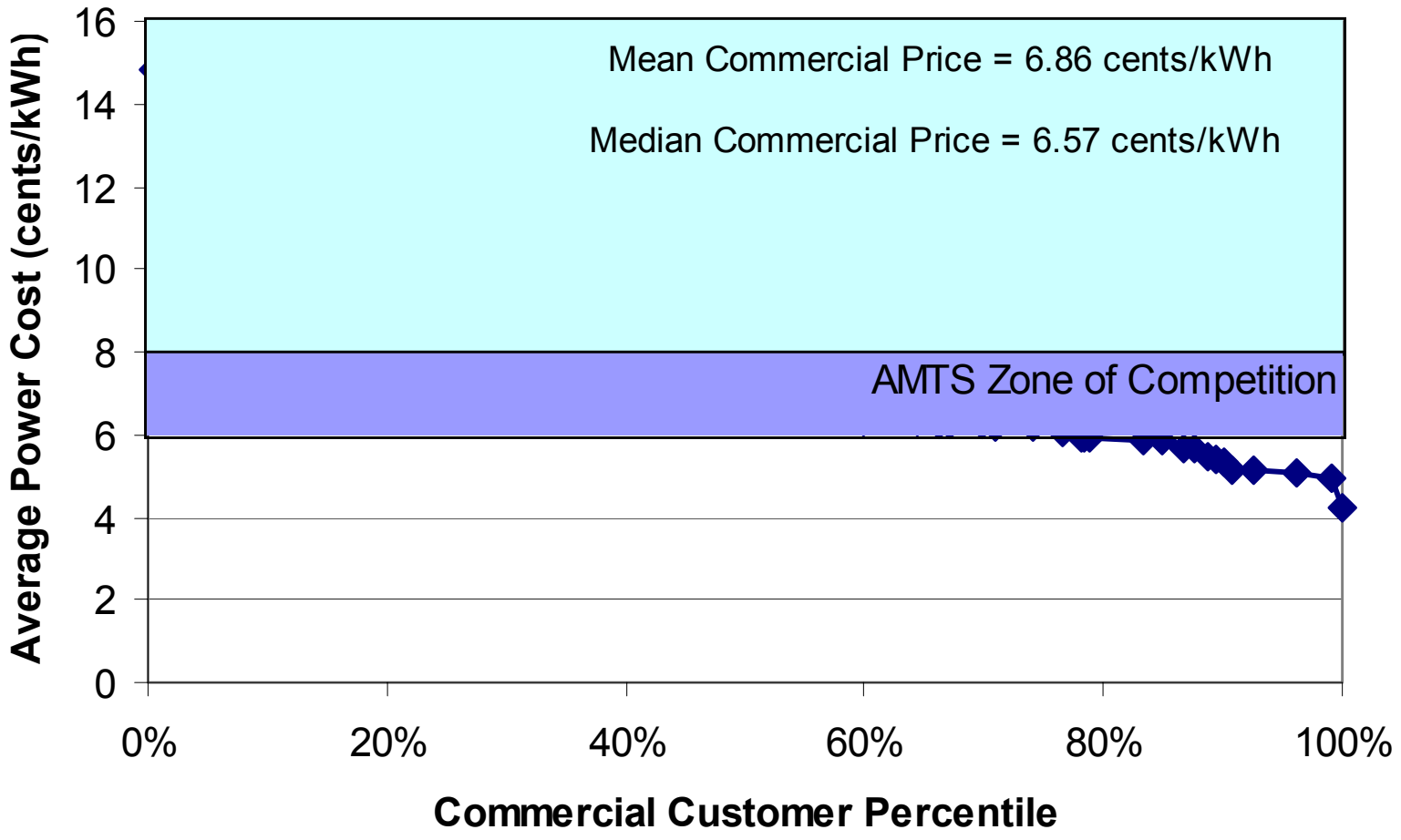
Distribution of Commercial Power Prices, 2000
and the Competitiveness of AMTS



Economic Market Potential

Value Proposition	AMTS Share	MW
Power Only -- Baseload	7%	2,600
CHP -- Hot Water	22%	6,800
BCHP -- Heat/Cool	4%	1,800
Direct CHP	40%	3,100
Peak Shaving	15%	12,000
Peak Shaving w Reliability	30%	5,400
Waste Fuels	~100%	~ 500
Oil and Gas Industry	~100%	~ 3,000

Share = % of technical potential that is economic (reflects geographic applicability)

MW = total economic potential market

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Market Positioning with other DG Options

- The AMTS will compete in DG markets from 100 kW to 1,000 kW
- While there will be competition in the this market from both fuel cells and reciprocating engines, market positioning is complementary
  - ✓ The ARES improvements will have the greatest impact on systems and applications greater than 1 MW
  - ✓ Much of the development emphasis for advanced fuel cells is focused on the lower capacity residential, small commercial and transportation markets
  - ✓ Fuel cell/AMTS hybrids in the long term offer the potential for higher efficiencies
- The AMTS is positioned between RE and Fuel Cell technologies
  - ✓ Greater near to mid term potential than fuel cells with more flexibility in applications (peaking, reliability, or baseload, load following) and greater flexibility in fuel use (gas, oil, waste fuels, and variable quality fuels)
  - ✓ Superior environmental signature and fuel flexibility may give AMTS advantages compared to RE technology in certain applications and areas

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Market Issues

- Interconnection and utility interface are critical issues
- Retail tariffs can promote or prohibit the market
- Standby/back-up rates are key to economics
- DG emissions standards could enhance the position of microturbines
- Market acceptance requires development of sales/service infrastructure, and documented performance and reliability

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